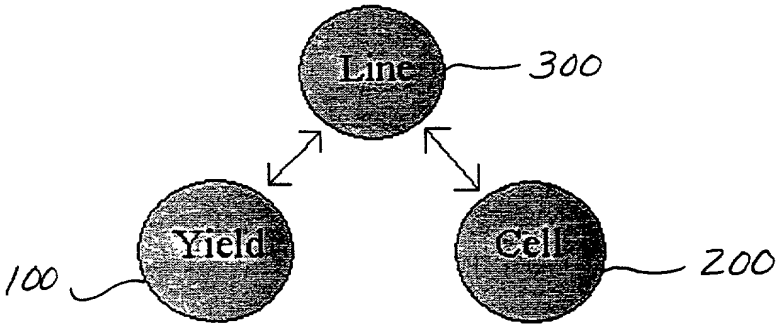

FIG. 1

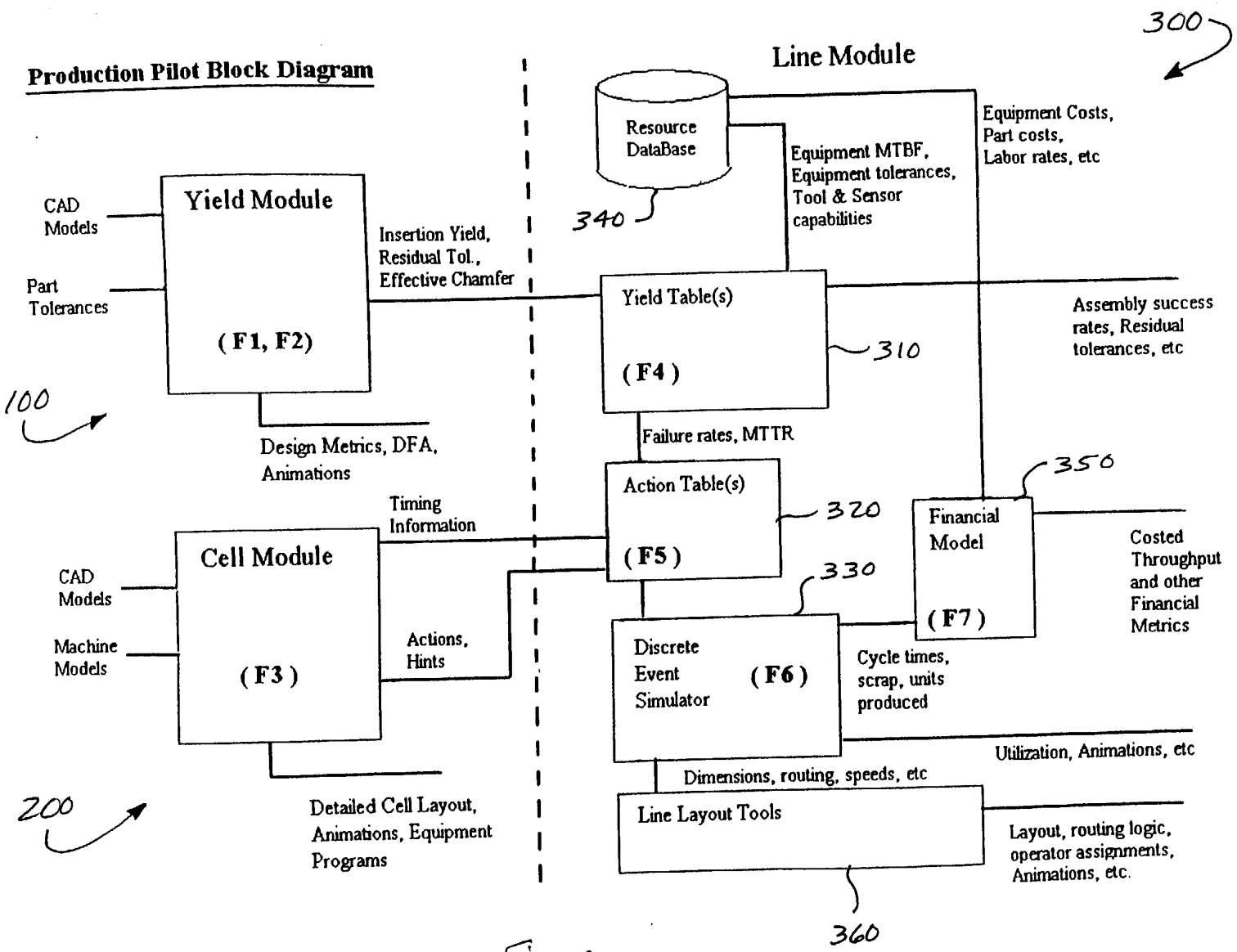
Production Pilot Block Diagram
Line Module
300
Resource DataBase
340
Equipment MTBF, Equipment tolerances, Tool & Sensor capabilities
Equipment Costs, Part costs, Labor rates, etc
CAD Models
Part Tolerances
Yield Module
(F1, F2)
Insertion Yield, Residual Tol., Effective Chamfer
Yield Table(s)
(F4)
310
Assembly success rates, Residual tolerances, etc
100
Design Metrics, DFA, Animations
Failure rates, MTTR
Action Table(s)
(F5)
320
Timing Information
Financial Model
(F7)
350
Costed Throughput and other Financial Metrics
CAD Models
Machine Models
Cell Module
(F3)
Actions, Hints
330
Discrete Event Simulator
(F6)
Cycle times, scrap, units produced
Utilization, Animations, etc
Dimensions, routing, speeds, etc
200
Detailed Cell Layout, Animations, Equipment Programs
Line Layout Tools
Layout, routing logic, operator assignments, Animations, etc.
360

Fig. 2

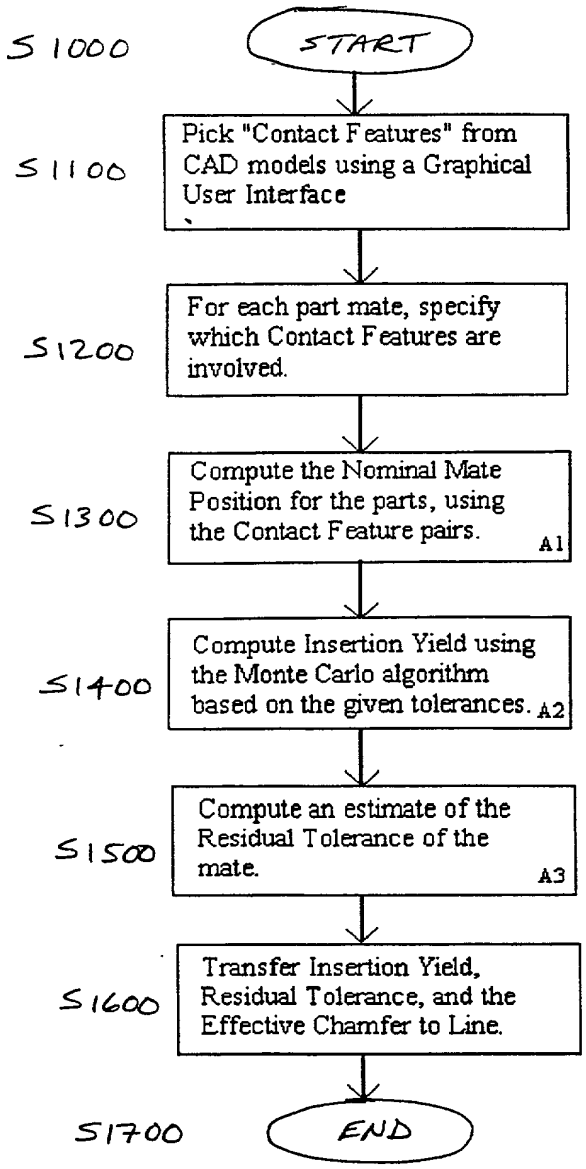
S1000
START
Pick "Contact Features" from CAD models using a Graphical User Interface
S1100
For each part mate, specify which Contact Features are involved.
S1200
Compute the Nominal Mate Position for the parts, using the Contact Feature pairs.
A1
S1300
Compute Insertion Yield using the Monte Carlo algorithm based on the given tolerances.
A2
S1400
Compute an estimate of the Residual Tolerance of the mate.
A3
S1500
Transfer Insertion Yield, Residual Tolerance, and the Effective Chamfer to Line.
S1600
S1700
END

Fig. 3

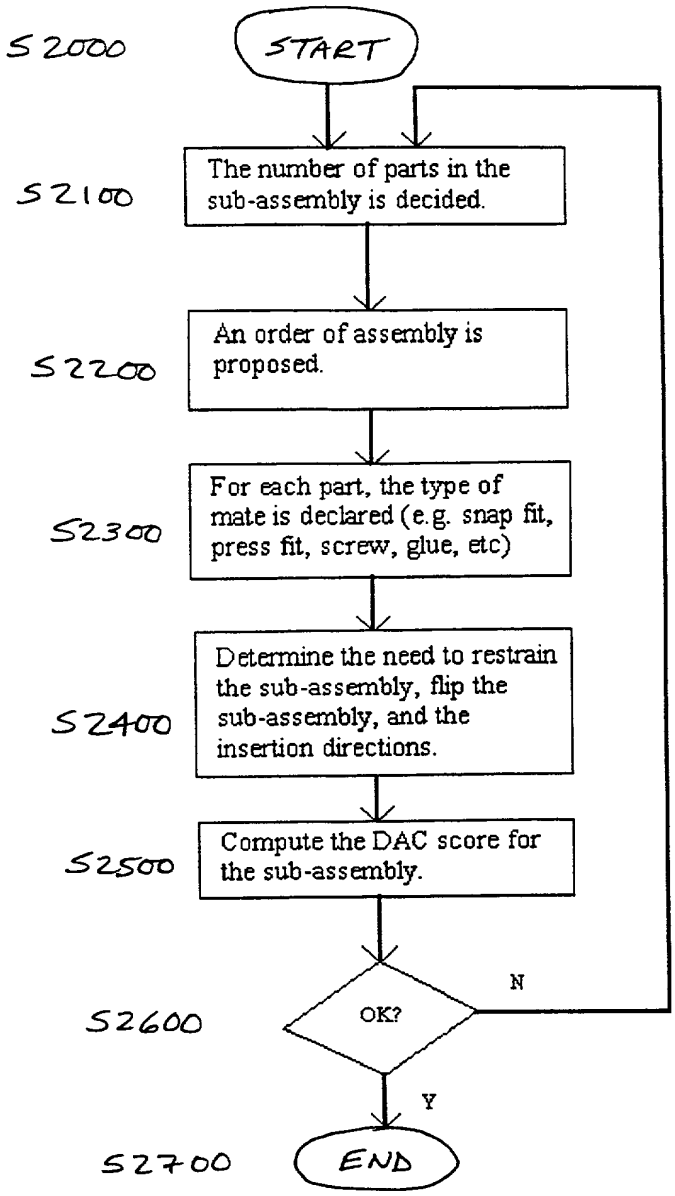
S2000
START
The number of parts in the sub-assembly is decided.
S2100
An order of assembly is proposed.
S2200
For each part, the type of mate is declared (e.g. snap fit, press fit, screw, glue, etc)
S2300
Determine the need to restrain the sub-assembly, flip the sub-assembly, and the insertion directions.
S2400
Compute the DAC score for the sub-assembly.
S2500
OK?
S2600
N
Y
END
S2700

Fig. 4

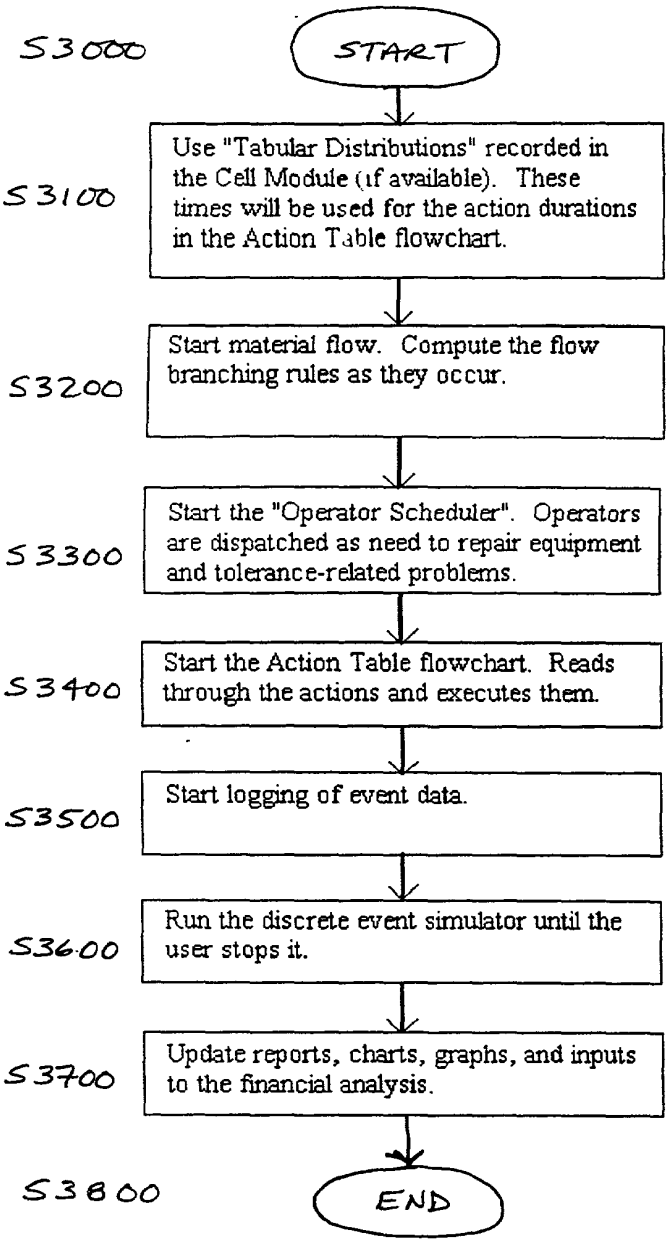
S3000
START
Use "Tabular Distributions" recorded in the Cell Module (if available). These times will be used for the action durations in the Action Table flowchart.
S3100
Start material flow. Compute the flow branching rules as they occur.
S3200
Start the "Operator Scheduler". Operators are dispatched as need to repair equipment and tolerance-related problems.
S3300
Start the Action Table flowchart. Reads through the actions and executes them.
S3400
Start logging of event data.
S3500
Run the discrete event simulator until the user stops it.
S3600
Update reports, charts, graphs, and inputs to the financial analysis.
S3700
END
S3800

Fig. 5

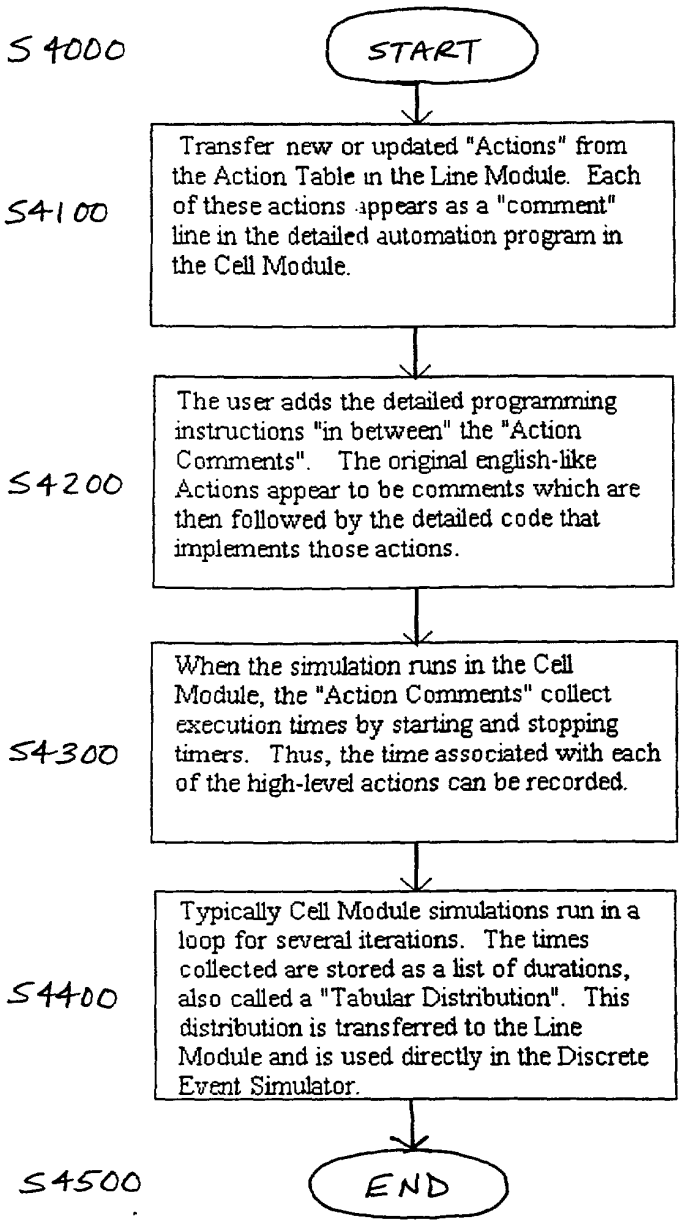
S4000
START
Transfer new or updated "Actions" from the Action Table in the Line Module. Each of these actions appears as a "comment" line in the detailed automation program in the Cell Module.
S4100
The user adds the detailed programming instructions "in between" the "Action Comments". The original english-like Actions appear to be comments which are then followed by the detailed code that implements those actions.
S4200
When the simulation runs in the Cell Module, the "Action Comments" collect execution times by starting and stopping timers. Thus, the time associated with each of the high-level actions can be recorded.
S4300
Typically Cell Module simulations run in a loop for several iterations. The times collected are stored as a list of durations, also called a "Tabular Distribution". This distribution is transferred to the Line Module and is used directly in the Discrete Event Simulator.
S4400
END
S4500

Fig. 6

Pick & Place Tolerance Stack-Up Chart

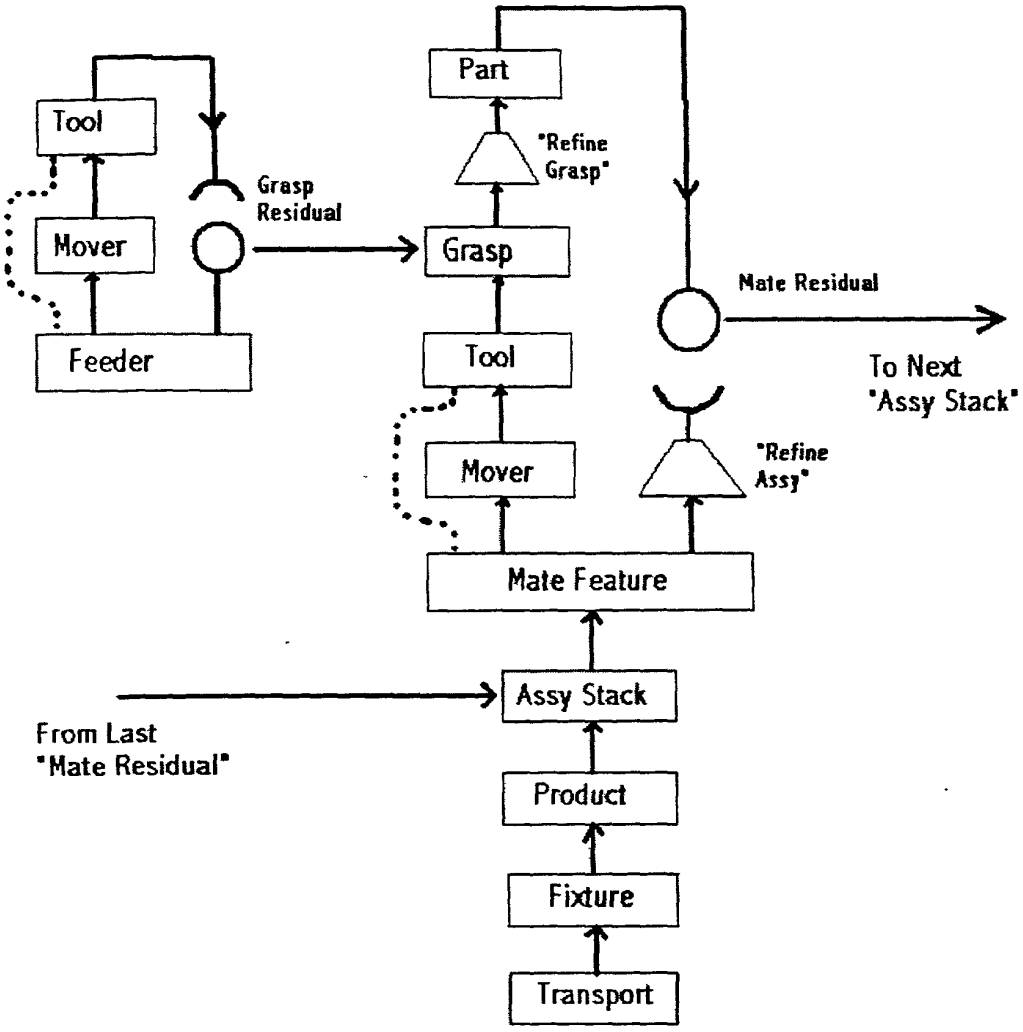

Fig. 7

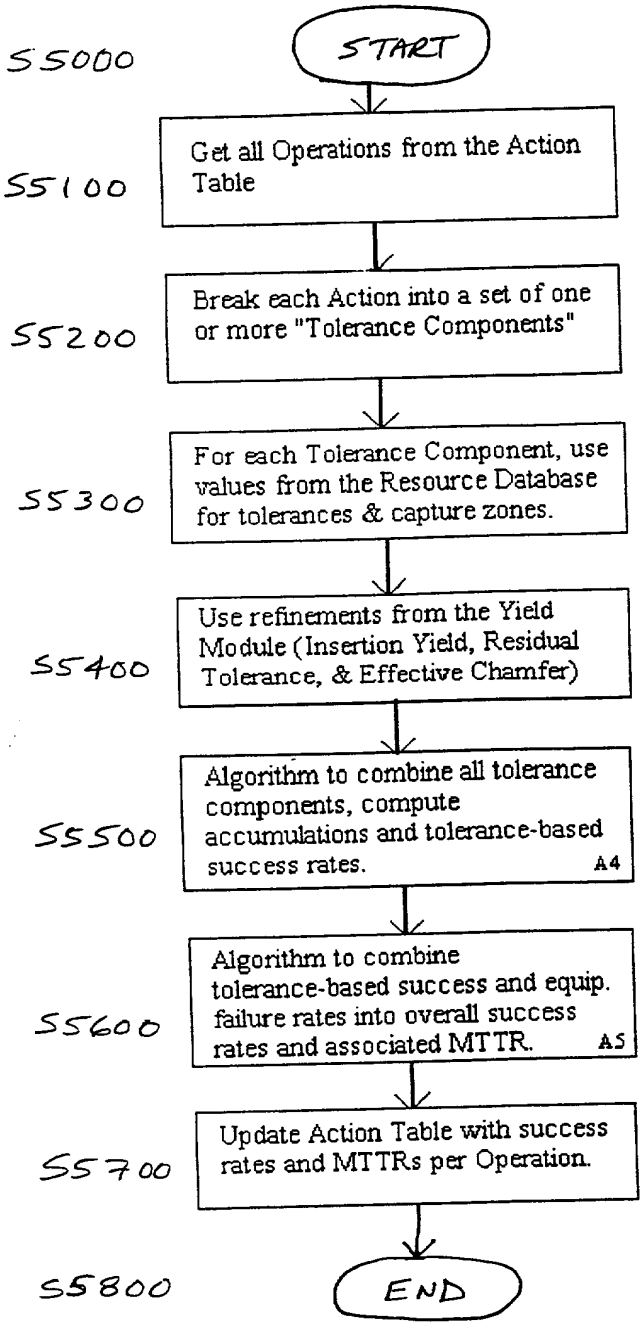
S5000
START
Get all Operations from the Action Table
S5100
Break each Action into a set of one or more "Tolerance Components"
S5200
For each Tolerance Component, use values from the Resource Database for tolerances & capture zones.
S5300
Use refinements from the Yield Module (Insertion Yield, Residual Tolerance, & Effective Chamfer)
S5400
Algorithm to combine all tolerance components, compute accumulations and tolerance-based success rates.
A4
S5500
Algorithm to combine tolerance-based success and equip. failure rates into overall success rates and associated MTTR.
A5
S5600
Update Action Table with success rates and MTTRs per Operation.
S5700
END
S5800

Fig. 8

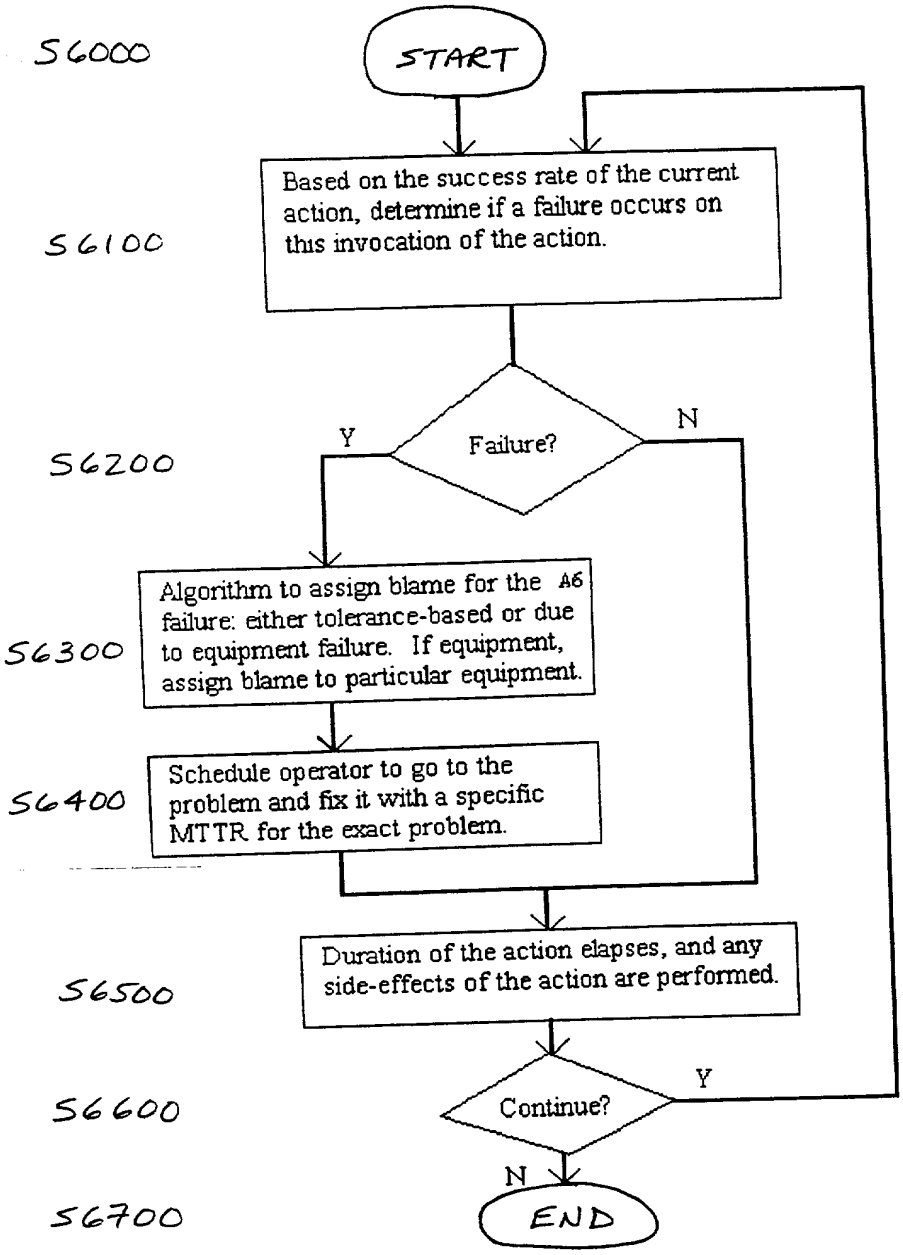
S6000
START
Based on the success rate of the current action, determine if a failure occurs on this invocation of the action.
S6100
Failure?
Y
N
S6200
Algorithm to assign blame for the failure: either tolerance-based or due to equipment failure. If equipment, assign blame to particular equipment.
S6300
Schedule operator to go to the problem and fix it with a specific MTTR for the exact problem.
S6400
Duration of the action elapses, and any side-effects of the action are performed.
S6500
Continue?
Y
N
S6600
END
S6700

Fig. 9

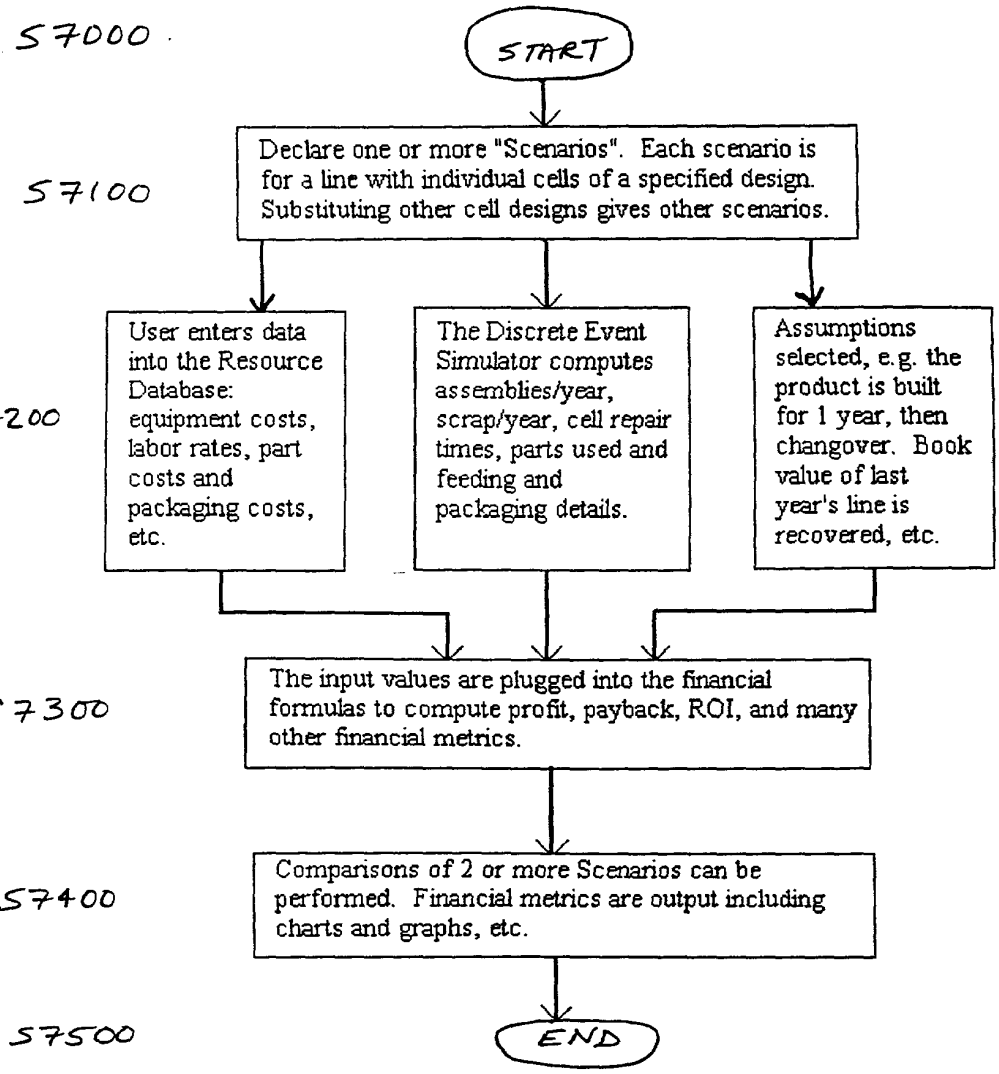
S7000
START
Declare one or more "Scenarios". Each scenario is for a line with individual cells of a specified design. Substituting other cell designs gives other scenarios.
S7100
User enters data into the Resource Database: equipment costs, labor rates, part costs and packaging costs, etc.
The Discrete Event Simulator computes assemblies/year, scrap/year, cell repair times, parts used and feeding and packaging details.
Assumptions selected, e.g. the product is built for 1 year, then changover. Book value of last year's line is recovered, etc.
S7200
The input values are plugged into the financial formulas to compute profit, payback, ROI, and many other financial metrics.
S7300
Comparisons of 2 or more Scenarios can be performed. Financial metrics are output including charts and graphs, etc.
S7400
END
S7500

Fig. 10